

Bloom & Breathe: Exploring Multimodal Olfactory Interventions for In-Car Road Rage Regulation

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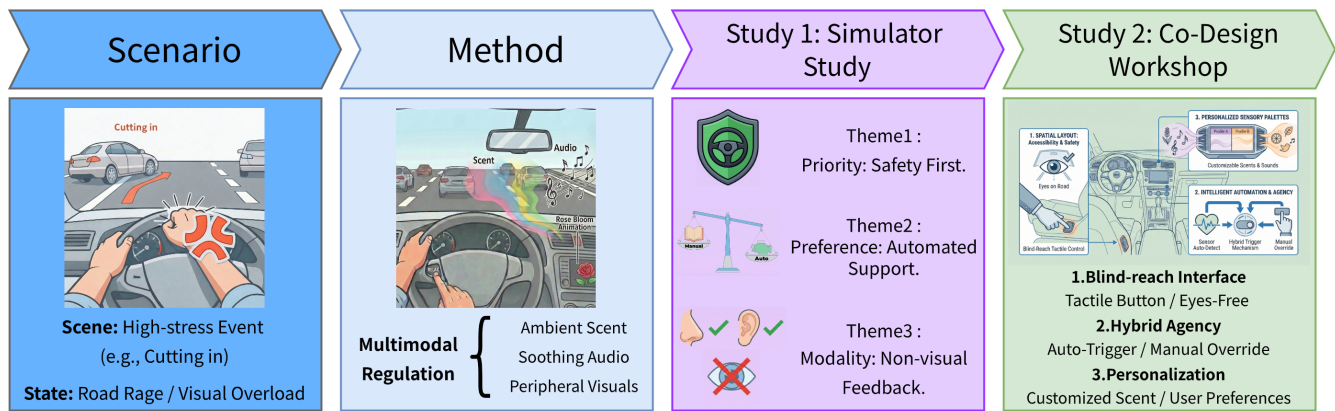


Figure 1: The research process and design outcomes. We address road rage (Scenario) through a multimodal intervention (Method). Based on safety and automation needs identified in exploratory interviews (Study 1), we co-designed the "Scentuary" system (Study 2), featuring a blind-reach tactile interface, hybrid automation, and personalized sensory palettes.

Abstract

Road rage poses significant safety risks, yet existing emotion regulation (ER) interventions often fail to accommodate the high cognitive load of driving. This work explores the design of multimodal, olfactory-led ER systems specifically for the automotive context. Through semi-structured interviews and co-design workshops with drivers, we identified a critical conflict between intervention efficacy and visual safety. Participants rejected screen-based feedback, prioritizing peripheral modalities (scent and audio) and favoring a "Hybrid Agency" model that combines context-aware automation with eyes-free manual control. Based on these findings, we propose The Scentuary, a conceptual framework for in-car ER that balances safety and restoration through personalized, non-intrusive sensory

environments. Our work contributes design guidelines for developing ambient interfaces that mitigate high-stress driving scenarios without adding to the driver's operational burden.

CCS Concepts

• **Human-centered computing** → **Participatory design**; *Haptic and somatic interaction*; *User centered design*; Empirical studies in HCI.

Keywords

In-Car System, Emotion Regulation, Road Rage, Olfactory Interaction, Multimodal Interfaces, Participatory Design

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1 Introduction

Driving is a high-stakes activity where negative emotions, particularly road rage [1, 21, 23], can severely impair judgment and

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increase accident risks. While various technology-mediated emotion regulation (ER) interventions exist—such as guided breathing or biofeedback visuals—they are predominantly designed for static environments like offices or homes [24]. Applying these visual-heavy or attention-demanding techniques to the driving context creates a dangerous paradox: the act of regulating emotions might itself compete for the driver's limited cognitive resources and visual attention, potentially compromising safety [20].

To address this, we investigate the potential of peripheral, non-visual interaction modalities, with a specific focus on olfactory interfaces as the primary modality, complemented by auditory and visual cues. Scent has a unique, direct pathway to the limbic system for rapid emotional modulation without occupying the visual channel [3, 19]. However, how to integrate scent with other modalities (audio/light) and how to balance system automation with user control in a moving vehicle remains underexplored. To bridge this gap, we pose two research questions:

- **RQ1:** How can olfactory-led multimodal interventions be integrated into the driving context to support drivers coping with road rage?
- **RQ2:** How should the interface and interaction of ambient scent and complementary feedback be designed to accommodate diverse driving situations?

In this paper, we first conducted semi-structured interviews (Study 1) to understand drivers' coping mechanisms and safety constraints. Subsequently, we organized co-design workshops (Study 2) where participants sketched their ideal in-car interfaces [11, 17]. Our findings reveal a strong preference for "Hybrid Agency"—systems that automatically detect stress but allow for eyes-free, tactile manual override—and "Invisible Interaction" via ambient scent and sound. We contribute design insights for creating safe, restorative in-car environments that regulate emotions "in the background" of the primary driving task [7].

2 Study 1: Simulator Study

In the first study, we aimed to learn from drivers about their experiences and needs regarding emotion regulation in stressful driving situations, particularly traffic congestion. We also sought to understand their perspectives on how an in-car emotion regulation system should be designed to provide timely and effective support while ensuring driving safety.

2.1 Methods

We used the semi-structured interview method in this study [9, 18]. The first author first developed the protocol and the interview questions and then discussed and revised them with the other authors. The protocol and interview questions were then tested and iterated in three pilot studies. We developed an interactive interface prototype as an exemplar design prompt to facilitate the conversation about design. The research protocol was approved by the institutional ethics board.

2.1.1 Prototype of Interactive Interface. The prototype consists of a physical button trigger, an aroma diffuser, a display screen, a speaker, and an STM32 microcontroller. The interaction design aims to provide immediate multisensory soothing [15]. Upon pressing

the button, the aroma diffuser is activated for 4–5 seconds to release a fragrance. Simultaneously, the system plays a 5-second excerpt of soothing music (excerpt from *"River Flows in You"*) and displays a 5-second animation of a blooming rose [10, 13]. For the olfactory stimulus, we used a diluted solution of rose essential oil mixed with water to ensure a subtle scent intensity.

2.1.2 Participants. We recruited 8 participants (2 female, 6 male) from a university campus, aged 21–25 ($M = 22.5$, $SD = 1.4$). All participants possessed valid driver's licenses with a minimum of 2 years of driving experience. They self-reported driving frequencies ranging from weekly to daily, ensuring familiarity with diverse traffic scenarios.

2.1.3 Procedure. After providing informed consent, participants completed a 7–10 minute audio-recorded session. The procedure involved a prototype demonstration, video-based road rage induction, and a trial under induced stress in our self-constructed intelligent cockpit. Subsequent semi-structured interviews focused on usage expectations, triggering modalities, and safety concerns in high-stress scenarios.

2.2 Results

We identified three main themes from the analysis: Safety is the Primary Concern, Automation over Manual Control, and Subtle Multisensory Comfort. To ensure anonymity, we refer to participant quotes as "P" (P1–8).

2.2.1 Theme 1: Safety is the Primary Concern. The participants generally emphasized the importance of considering driving safety when designing an emotion regulation device for road rage scenarios. This theme included the following two subthemes:

- **Visual Distraction is a Risk:** Most participants (P3, P4, P8) explicitly stated that animation on the central console creates distraction and danger. P3 noted, *"Animation affects safety; hope to change it to lighting regulation"*. P8 mentioned, *"Animation makes people distracted"*.
- **Preference for Integration:** Participants preferred the interface to look like an *"original factory accessory"* (P2, P3, P5, P8) rather than an add-on gadget, ensuring it blends into the driving environment without blocking views or operations.

2.2.2 Theme 2: Automation over Manual Control. Participants consistently reported that during high-stress negative affective states, their capacity to proactively initiate an intervention is severely compromised. The high cognitive load inherent to driving, compounded by emotional agitation, renders the manual operation of additional devices both impractical and potentially unsafe. Consequently, we identified two approaches centered on mitigating the driver's operational burden as sub-themes:

- **Adopting Automatic Triggering:** In road rage scenarios, such as being cut off by another vehicle or facing severe congestion, drivers are often too cognitively engaged or emotionally agitated to divert attention to a physical button. Participants (P1, P2, P4, P5, P7, and P8) expressed a strong consensus for automatic triggering based on sensing technologies. For instance, P4 suggested *"automatic triggering by detecting facial expressions"*, while P8 favored automation

when *"dangerous driving behaviors appear"*. They argued that the system should proactively detect anxiety or anger and intervene without requiring user input, as manual activation is likely to be neglected when the driver is focused on the immediate traffic conflict.

- **Voice as an Alternative:** If manual control is needed, Voice Command (P7, P8) was preferred over physical buttons to maintain hands-on-wheel safety. This modality mitigates the safety risks associated with reaching for a button during volatile driving moments, ensuring that the act of regulation does not itself become a safety hazard.

2.2.3 Theme 3: Multisensory Efficacy: Scent and Sound. Participants confirmed that multisensory experiences influence mental states, but the modalities must be carefully chosen for the driving context. We identified two sub-themes based on the interview results.

- **Scent and Music are Effective:** Almost all participants perceived scent as the most effective of the three modalities (scent, music, and animation) for regulating emotions. P4 and P8 emphasized that *"music and scent are significantly effective"*, while P5 noted that the combination *"soothed emotions"*.
- **Subtlety is the Key** In contrast to stimulating stimuli, drivers preferred subtle fragrances (P1, P5, P8) and soothing music (P4, P5). Notably, P2 cautioned that the *"scent cannot be too strong"*, highlighting the necessity for precise intensity control.

3 Study 2: Co-Design Workshop

From Study 1, we identified the key requirements for in-car ER support (i.e., prioritizing safety over visualization, reducing operational burden via automation, and leveraging subtle olfactory-auditory cues). However, gaps remain in our understanding of specific design realizations concerning the physical placement, sensory parameters, and multimodal orchestration within the vehicle. Therefore, Study 2 primarily aims to address RQ2, complementing Study 1: *"How should the interface, interaction, and multimodal feedback be designed to accommodate diverse driving situations?"*

3.1 Methods

We conducted co-design workshops to explore drivers' perspectives on the design of the interactive interface for in-car ER systems[6, 8]. This method was selected to gather participants' concrete expectations for such a device and to understand their needs in real-life scenarios and how to address them. Co-design workshops are also widely used in other HCI studies for exploring the design and use of technology-mediated mental health systems. This study was approved by the institution's ethical committee.

3.1.1 Participants. To ensure continuity in design preferences, we invited the same 8 participants from Study 1 to join the co-design sessions.

3.1.2 Procedure. Workshops were conducted in university meeting rooms, lasting approximately 20 minutes. After informed consent, the session proceeded in three stages: (1) Introduction, where we reiterated Study 1 findings (e.g., safety priority) to ground designs in driving constraints; (2) Sketching, where participants used car

cockpit templates to visualize and annotate their ideal scent, audio, and visual feedback mechanisms; and (3) Presentation & Discussion, where participants explained their concepts, followed by a group critique focused on reconciling preferences and safety.

3.1.3 Data Analysis. We transcribed and analyzed the workshop recordings using Braun and Clarke's method of reflexive thematic analysis[4]. The first author iteratively coded the transcripts, utilizing the participants' sketches to complement the textual data by visualizing spatial configurations and sensory preferences. The codes were classified into candidate themes, discussed by all authors, and iteratively refined into the final themes.

3.2 Results

Analysis of the sketches and annotations revealed three dominant design themes: Spatial Safety, Intelligent Automation, and Personalized Sensory Palettes. To protect anonymity, we refer to participant quotes as "P#", where P is followed by the participant number (P1-8).

3.2.1 Spatial Layout: Balancing Accessibility and Safety. Participants generally engaged in a trade-off between accessibility and visual safety. While some (like P1) explored tactile placement on the seat side for eyes-free access, others focused on the visual domain. Participant P6 explicitly annotated that the "center console screen" was the preferred location for visual feedback, arguing that *"other locations are more likely to be distracting"* (P6). This suggests that while visual feedback is secondary, if implemented, it should remain in centralized, predictable zones rather than intruding into the driver's primary field of view (e.g., the windshield).

3.2.2 Intelligent Automation & Agency. Consistent with the "burden reduction" theme in Study 1, sketches from P3 and P4 prominently featured "automatic detection" and "emotion recognition" modules. P3 envisioned a system where "automatic detection is available" but emphasized that user agency must be preserved, noting that "concentration can be controlled" manually. This highlights a dual need: drivers want the system to be proactive during crisis moments but require the ultimate authority to override sensory intensity.

3.2.3 Personalized Sensory Palettes. The sketches revealed highly diverse preferences for sensory content, validating the need for a customizable system.

- **Olfactory:** P2 requested a "lighter" scent, interestingly suggesting *"something that smells like food"*, contrasting with P4's preference for traditional *"Lavender essential oil"*. P1 also flagged the prototype scent as *"too pungent"*.
- **Visual/Auditory:** In terms of feedback style, participants converged on calming metaphors. P8 specified a "Natural" style, and P7 described the desired visual aesthetic as "Healing." P5 similarly called for "Soothing" music styles. These annotations collectively indicate that there is no "one-scent-fits-all" solution; the system must support personalized sensory profiles.

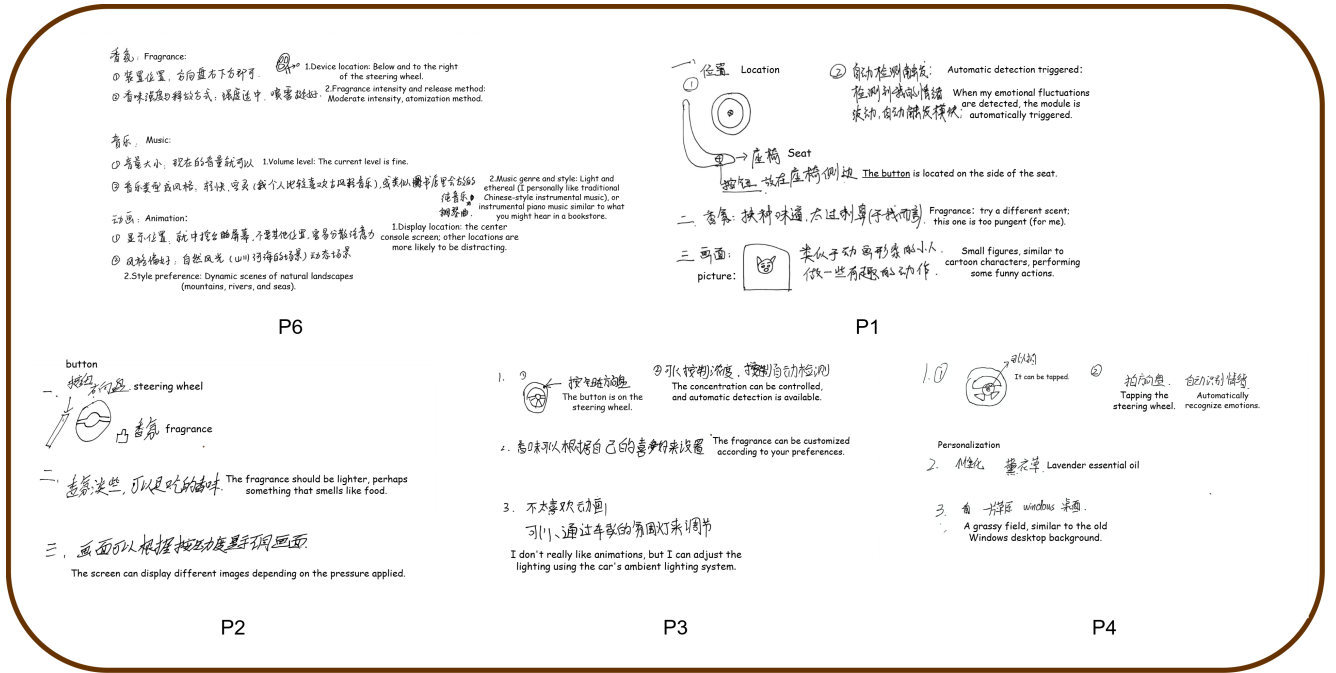


Figure 2: Selected participant sketches illustrating key design requirements. P6 arguing for the center console location to minimize visual distraction; P1 proposing a tactile button on the side of the seat for eyes-free accessibility; P3 highlighting the need for automatic detection combined with manual concentration control; P2 & P4 showing diverse scent preferences, indicating the need for personalization.

4 Discussion

Our findings offer answers to our two research questions regarding the integration and design of in-car emotion regulation (ER) systems.

4.1 Peripheral Interaction: Prioritizing Non-Visual Modalities

RQ1 asked how ER interventions can be integrated into the driving context. Our studies highlight that safety is the absolute prerequisite for integration. The driving environment necessitates a "zero-tolerance" approach to visual distraction, distinguishing it from other static contexts.

- **Shift to Ambient Channels:** To integrate ER without competing for the driver's visual attention, the primary feedback channel must shift from visual interfaces to olfactory and auditory modalities. Visual elements, if present, should be restricted to peripheral ambient lighting rather than focal screens to maintain the driver's gaze on the road.
- **Automation as a Safety Feature:** Integration also implies minimizing operational burden[2]. Since manual triggering is often impractical during high-stress road rage events due to cognitive overload, context-aware automation (triggered by physiological or vehicle data) is not merely a convenience feature but a safety necessity, allowing the system to intervene without requiring physical interaction.

4.2 Hybrid Agency: Balancing Automation with User Control

RQ2 asked how the interface and feedback should be designed to accommodate diverse situations. Our co-design results suggest that a rigid design fails to address individual sensitivities and the dynamic nature of driving.

- **Hybrid Agency (Interaction):** To balance the need for rapid intervention with user autonomy, we propose a "Hybrid Agency" design. The system should proactively initiate support during crisis moments (automation) but must provide simple, eye-free mechanisms (e.g., voice commands or tactile blind-reach buttons) for drivers to adjust intensity or disengage immediately (manual agency).
- **Personalized Sensory Profiles (Feedback):** Drivers' preferences for "calming" stimuli vary drastically. A scent or sound that soothes one user might irritate another, potentially exacerbating stress. Future interfaces should act as open platforms, allowing users to pre-configure "Sensory Profiles" (e.g., specific scents, music genres, and intensity limits) while parked[5, 12, 16]. This ensures that when the system activates on the road, the multimodal feedback acts as a familiar comfort rather than an intrusive surprise.

4.3 The "Scentuary" Conceptual Framework

Synthesizing the findings from our studies, we propose "Scentuary"—a conceptual framework for in-car emotion regulation. It functions as a restorative sanctuary during high-stress driving by combining Peripheral Interaction (Section 4.1) via ambient scent and audio, with a Hybrid Agency mechanism (Section 4.2) that balances safety and user control.

5 Conclusion and Future Work

In this work, we explored the design of multimodal olfactory interventions to mitigate road rage. Through interviews and co-design sketching, we identified that effective in-car emotion regulation must be subtle, automated, and highly personalized. We contribute design insights emphasizing peripheral interaction and hybrid control mechanisms.

However, this study has several limitations. First, our small, homogeneous participant pool (young, educated campus population) and the repeated participation across studies may introduce bias and constrain generalizability. Future studies must engage more diverse user groups (e.g., older drivers, novice drivers) across varying contexts (urban vs. highway). Second, using low-fidelity prototypes in a static setting limits ecological validity. Future work will implement a high-fidelity prototype in a motion-based driving simulator to quantitatively measure physiological stress (e.g., HRV, EDA) and driving performance metrics [14, 22].

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